Congener-specific Levels of Dioxins and Dibenzofurans in U.S. Food and Estimated Daily Dioxin Toxic Equivalent Intake

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Food, especially meat, milk, and fish, is the immediate source of almost all polychlorinated dibenzo-*p*-dioxins (PCDDs), dibenzofurans (PCDFs), and dioxinlike compounds in the general population. To estimate intake of these highly toxic compounds, we performed congener-specific dioxin analyses for the first time on U.S. food for 18 dairy, meat, and fish samples from a supermarket in upstate New York. 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (TCDD, "dioxin") toxic equivalents (TEqs) on a wet weight basis for the dairy products ranged from 0.04 to 0.7 ppt, meat TEqs ranged from 0.03 to 1.5 ppt, and fish TEqs ranged from 0.02 to 0.13 ppt. Previous human breast milk and infant formula analyses were used with the current preliminary food data to estimate a range of dioxin intake for Americans. Average daily food intake of TEqs for an adult weighing 65 kg was estimated to be between 0.3 and 3.0 pg/kg body weight, for a total of 18–192 pg TEq, using 1986 American consumption rates. Due to the relatively high level of PCDDs and PCDFs commonly found in human breast milk from American women and from women in other industrial countries, a nursing infant may consume an average of 35–53 pg TEq/kg body weight/day in its first year of life. This may be compared with the current U.S. EPA virtually safe dose of 0.006 pg TCDD/kg body weight per day over a 70-year lifetime, based on an upper limit cancer risk of 10^{-6}, or the 10 pg/kg/day used by some European government agencies. *Key words*: dibenzofurans, dioxins, food contamination, human milk contamination, toxic equivalents. *Environ Health Perspect* 102:962–966 (1994)

Polychlorinated dibenzo-*p*-dioxins (PCDDs) and dibenzofurans (PCDFs) are highly toxic and persistent compounds that especially accumulate in tissue lipid. These compounds are consistently found in relatively high levels in humans living in industrialized countries and in much lower levels in persons living in less developed countries (*1*). The most toxic and persistent congeners are 2,3,7,8-substituted PCDDs and PCDFs, due to their high affinity for the Ah receptor and resistance to biotransformation (*2*). Almost all PCDDs and PCDFs found in humans from the general population are believed to come from food, especially meat, milk, fish, and their by-products (*3,4*). A number of health studies performed on populations occupationally or environmentally exposed to PCDDs and PCDFs or closely related chemicals found a variety of health effects, similar to toxic effects reported in animal studies, either beginning soon after exposure, or in the case of cancer mortality, after a latency period (*5–11*). Since the exact level of PCDDs and PCDFs that causes various health effects in humans is unknown, it is important to identify the immediate source of these chemicals in the general population.

PCDD and PCDF congeners exist in biological samples as mixtures in varying amounts. To simplify risk assessment and regulatory control, the concept of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) toxic equivalents (TEqs) has been developed. In this concept, the toxicity of the congeners in relation to TCDD is assessed based on *in vitro* and *in vivo* studies. This relative toxicity or toxic equivalency factor (TEF) is used to weight and calculate the additive toxicity of the congeners present in a sample as related to TCDD. TCDD, the most toxic dioxin, is arbitrarily weighted with a TEF of 1.0. Our intake calculations are based on the total TEq using the currently accepted U.S. EPA and international dioxin toxic equivalency factors (*12–14*).

In 1989, a German study reported dioxin levels from 22 food samples from West Germany and estimated daily intake of dioxin TEqs in the Federal Republic of Germany. The samples included meat, fish, dairy products, fruits, and vegetables. Total daily intake, using dioxin TEFs in use at that time, was estimated as 90.2 pg or 1.5 pg TEq/kg for a 60-kg adult, with negligible contributions from fruits and vegetables (*3*).

A 1989 Canadian report used analyses of four meat, two dairy, and five fruit/vegetable samples to estimate Canadian daily intake of dioxin TEqs. Although many of the samples had nondetectable levels of most of the PCDD and PCDF congeners, 91.2 pg TEq, or 1.52 pg TEq/kg for a 60-kg adult was estimated as the average adult daily intake (*15*). In Canada at the time, a maximum allowable daily intake for PCDDs and PCDFs of 10 pg TEq/kg body weight was suggested, and a collaborative effort by the Canadian government was underway to develop national guidelines (*16*).

Subsequently, other studies in Germany (*4*), the Netherlands (*17*), and the United Kingdom (*18*) have reported intakes in the range of 70–125 pg TEq/day, using the current commonly accepted international dioxin toxic equivalency factors (*13,14*), which are identical to current U.S. EPA estimates (*12*). One of the German food studies includes ranges of PCDD and PCDF levels in 107 food analyses to better reflect the variability between samples (*4*).

These congener-specific studies of PCDDs and PCDFs in food from a number of industrial countries found that meat, milk, and fish products account for about 95% of human general population intake of PCDDs and PCDFs. Fruits and vegetables, which usually contain almost no dioxins or dibenzofurans, contribute a negligible amount to human intake, whereas air and water are a secondary source of exposure to these compounds (*3,4,17,19–22*). Although human tissue levels in the United States have been well characterized during the past decade, congener-specific analysis of PCDDs and PCDFs in American food, using state-of-the-art detection levels, has rarely been undertaken. Without this data, the source of PCDDs and PCDFs in Americans cannot be clearly characterized, nor can effective measures be undertaken to decrease food levels of these highly toxic chemicals in the future.

Methods

To gather preliminary food data, we collected and analyzed 18 individual samples of meat, fish, and dairy products from a New York State supermarket. To address dioxin intake for infants, we worked with data from our previous studies of human milk from nursing mothers and soy-derived infant formula (*23,24*). We elected to sample only New York supermarkets.

Because levels and patterns of dioxins and dibenzofurans in human tissue from widely separated areas in the United States are quite similar, we assumed that food from various regions is probably also similar in PCDD and PCDF content. In addition, food in U.S. supermarkets is often shipped long distances from the original source, and standard brands are distributed

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A portion of this work was funded by the Warsh-Mott Legacy of the CS Fund. Thanks are extended to Avi Silber, Frank Leu, and Ruth Stento for manuscript preparation.
Received 23 May 1994; accepted 30 August 1994.

throughout the country.

Samples of meat, fish, and dairy products were purchased from an upstate New York supermarket in the early 1990s. Samples were frozen at -20°C and shipped on dry ice to two dioxin laboratories for analysis by high-resolution gas chromatography/mass spectroscopy following extraction and clean-up. Samples were analyzed as purchased, consistent with the way most studies report food dioxin analyses. Each laboratory has been certified by the World Health Organization for dioxin analysis of human tissue and also has passed interlaboratory dioxin food validation testing.

Samples were blended with sodium sulfate, packed into a 6-cm diameter column, and extracted with dichloromethane/cyclohexane (1:1). After changing to hexane solvent, the extracts were purified using the method of Smith et al. (*25*).

A 60-m DB5 column was connected directly to the ion source. Splitless injections were made (2 µl) at an injection temperature of 280°C and with a splitless period of 90 sec. Peak-area measurements were made by interactive data processing. Quantification was based on the summed areas of the peaks in the two channels relevant to each compound.

Table 1. Dioxins, dibenzofurans, and dioxin TEqs in fish from a U.S. supermarket (ppt, wet weight)[a]

Compound	TEF	Haddock	Haddock fillet	Crunchy haddock	Perch	Cod
2,3,7,8-TCDD	1	ND (0.01)	0.008	0.03	0.04	ND (0.01)
1,2,3,7,8-PeCDD	0.5	ND (0.01)	ND (0.006)	0.05	0.05	0.01
1,2,3,4,7,8-HxCDD	0.1	0.01	ND (0.009)	0.05	—[b]	ND (0.01)
1,2,3,6,7,8-HxCDD	0.1	0.03	0.021	0.1	0.10	0.02
1,2,3,7,8,9-HxCDD	0.1	0.02	NA	0.1	0.03	ND (0.01)
1,2,3,4,6,7,8-HpCDD	0.01	0.12	0.047	0.35	0.18	0.1
OCDD	0.001	0.56	0.268	2.23	1.15	0.67
2,3,7,8-TCDF	0.1	0.04	0.02	0.05	0.73	0.03
2,3,4,7,8-PeCDF	0.5	0.01	0.007	0.04	0.14	ND (0.01)
1,2,3,7,8-PeCDF	0.05	0.01	0.008	0.03	0.1	ND (0.01)
1,2,3,4,7,8-HxCDF	0.1	0.01	ND (0.008)	0.04	0.02	ND (0.01)
1,2,3,6,7,8-HxCDF	0.1	0.01	ND (0.007)	0.03	0.03	ND (0.01)
2,3,4,6,7,8-HxCDF	0.1	0.01	ND (0.006)	0.05	0.04	ND (0.01)
1,2,3,7,8,9-HxCDF	0.1	ND (0.01)	ND (0.01)	0.03	ND (0.01)	ND (0.01)
1,2,3,4,6,7,8-HpCDF	0.01	0.01	0.007	0.05	0.03	0.02
1,2,3,4,7,8,9-HpCDF	0.01	ND (0.01)	ND (0.01)	0.05	ND (0.01)	ND (0.01)
OCDF	0.001	0.03	ND (0.014)	0.14	0.04	ND (0.01)
Total PCDDs		0.75	0.35	2.91	1.55	0.815
Total PCDFs		0.14	0.07	0.51	1.14	0.09
PCDDs and PCDFs		0.89	0.42	3.42	2.69	0.905
Total PCDD and PCDF TEQs		0.03	0.02	0.13	0.023	0.023

Abbreviations: CDD, chlorinated dibenzodioxin; CDF, chlorinated dibenzofuran; T, tetra; Pe, penta; Hx, hexa; Hp, hepta; O, octa; ND, not detected within detection limits shown in parentheses; NA, not available.
[a]Analyses by Food Science Laboratory, Norwich, England. Half of detection limits for nondetected congeners used in calculation.
[b]"Fused" peaks: a small peak not fully resolved from one much larger. The contribution from 1,2,3,4,7,8-HxCDD is small.

Results

The results from 18 U.S. supermarket food samples are presented on a whole- (or wet) weight basis, in order to be more representative of the way food is purchased and consumed. However, it should be noted that food preparation and/or cooking method can alter PCDD and PCDF levels in the final food product.

Table 1 presents congener-specific data for five fish samples. Total PCDDs and PCDFs range from 0.42 to 3.42 ppt. Total TEqs are 0.03 ppt for haddock, 0.02 for haddock fillet, 0.13 ppt for crunchy haddock, 0.023 ppt for perch, and 0.023 ppt for cod, all on a wet-weight basis. These fish PCDD/PCDF levels appear lower than German and Dutch findings.

Table 2 presents meat products; total PCDDs and PCDFs range widely from 0.8 to 61.8 ppt for eight samples that include beef, pork, lamb, and chicken. For meat, total dioxin TEqs are 1.5 ppt for ground beef, 0.04 ppt for beef rib sirloin tip, 0.3 ppt for pork chops, 0.4 ppt for lamb sirloin, 0.03 ppt for cooked ham, 0.65 ppt for beef rib steak, 0.12 ppt for bologna, and 0.03 ppt for chicken drumstick, on a wet-weight basis.

Table 3 presents results for five dairy products: cottage cheese, soft blue cheese, heavy cream, soft cream cheese, and American cheese slices. A variation in total PCDDs and PCDFs is seen from 0.9 ppt for cottage cheese to 19 ppt for soft blue cheese. Dairy product TEqs, on a wet-weight basis, are 0.04 ppt for cottage cheese, 0.7 ppt for soft blue cheese, 0.4 ppt for heavy cream, 0.3 ppt for soft cream cheese, and 0.3 ppt for American cheese slices.

The range of dioxin TEq levels from the individual samples was used to estimate daily intake for each of the food groups, meat, fish, and dairy. Previously reported results of PCDD and PCDF analyses of cow's milk, human breast milk, and infant formula are used to calculate TEq intake for infants and children in Tables 4 and 5 (*23,24*). Consumption rates used in Tables 4 and 5 are from a 1986 publication of the U.S. Environmental Protection Agency, Office of Radiation Programs, a publication currently used by the EPA to estimate U.S. food and dioxin intake (26).

Table 4 presents our calculations of daily intake of dioxin TEqs in adults by food category. The average daily intake (TEq/kg) is calculated assuming an average of 65 kg body weight for adults. Total daily TEq intake from beef ranges from 3.52 to 132 ppt, pork ranges from 0.84 to 8.40 ppt, poultry from one sample contributes 0.93 ppt, fish ranges from 0.36 to 2.34 ppt, cow's milk from one sample contributes 10.16 ppt, and other dairy products range from 2.20 to 38.50 ppt. The dioxin TEqs in these samples provide a range for our estimated total intake of from 18 to 192 pg of TEq, or 0.3 to 3 pg/kg body weight/ day.

Table 5 presents intake for males of different age groups. Dioxin intake varies considerably from infants to adults due to different dietary habits. Concern has been expressed about infant intake of PCDDs and PCDFs from breast-feeding (*27,28*). The dioxin TEqs of 0.43 and 0.64 ppt, wet weight, were from pooled breast milk samples from women from Binghamton, New York (n = 22) and Los Angeles (n = 21) (*23*). Assuming 1 year of breast-feeding, with an average consumption rate of 600 g/day for the first year of life, daily TEq intake would be 258–384 pg/day or 35–53 pg/kg body weight. Analyses of soy-derived infant formulas found few dioxin congeners present in detectable amounts; therefore, a formula-fed infant would have a much lower intake of TEqs, approximately 0.54–1.2 pg/day or 0.07–0.16 pg/kg body weight/day for the first year of life. Daily TEq intake for males ranges from 20 to 434 pg/day for ages 1–4; for ages 5–9, 24–552 pg/day; for ages 10–14, 28–658 pg/day; and for ages 15–19, 30–737 pg/day. For males 20 years or older, daily TEq intake ranges from 19 to 553, or 0.3–8 pg/kg body weight. Children have a higher daily TEq intake per kilogram than adults: 1.4–32 pg/kg for ages 1–4, 1–27 pg/kg for ages 5–9, 0.7–16 pg/kg for ages 10–14, and 0.4–11 pg/kg for ages 15–19. These intake estimates for males differ slightly from those in Table 4, which uses U.S. mean consumption rates (for both males and females) and an average weight of 65 kg. Table 5 also uses a total consumption rate for meat, rather than presenting beef, pork, and poultry separately, as in Table 4.

Conclusions

Although levels and bioavailability of PCDDs and PCDFs may vary in prepared food, our analyses results and intake estimates are consistent with those found in similar raw food samples by researchers in the United Kingdom, the Netherlands, Germany, and Canada (*3,4,15,17,18,29*). The large variation of PCDD and PCDF levels in these samples illustrates the difficulty in estimating intake for a large population with highly individual dietary habits. We believe the range calculated here constitutes a reasonable preliminary approximation of American dietary dioxin TEq intake, which should be followed with a more comprehensive and systematic sampling.

The low figure of 0.3 pg of TEqs/kg body weight/day for adults exceeds the U.S. EPA's virtually safe dose of 0.006 pg/kg/day, producing an upper-limit cancer risk of 10^{-6} (*30*). The levels we estimated for infants in the first year of life, 35–53 pg/kg of body weight per day, also exceed the maximum allowable dioxin TEq intake of 10 pg/kg/day established by Germany, the U.K. Department of Environment, the Swiss Institute of Toxicology, and the Ontario Ministry of Environment.

Interestingly, should a vegetarian diet provide an intake of about 2% of the general population total dioxin intake, the daily total adult dioxin TEq intake might be reduced

Table 2. Dioxins, dibenzofurans, and dioxin TEqs in meat products from a U.S. supermarket (ppt, wet weight)[a]

Sample congener	TEF	Ground beef	Beef rib sirloin tip	Pork chops	Lamb sirloin	Cooked ham	Beef rib steak	Bologna	Chicken drumstick
2,3,7,8-TCDD	1	0.019	0.005	0.013	0.052	ND (0.006)	0.028	0.015	0.011
1,2,3,7,8-PeCDD	0.5	0.062	0.01	0.041	0.28	ND (0.009)	0.208	0.042	ND (0.011)
1,2,3,4,7,8,-HxCDD	0.1	—[b]	—[b]	—[b]	0.295	—[b]	—[b]	0.044	ND (0.017)
1,2,3,6,7,8-HxCDD	0.1	0.496	0.03	0.282	0.631	0.055	1.981	0.199	0.04
1,2,3,7,8,9-HxCDD	0.1	0.087	0.011	0.044	0.241	0.007	0.616	0.058	ND (0.014)
1,2,3,4,6,7,8-HpCDD	0.01	1.157	0.117	8.197	3.531	0.437	12.065	1.033	0.133
OCDD	0.001	2.262	0.414	50.742	3.916	2.2	15.825	2.271	0.74
2,3,7,8-TCDF	0.1	0.025	0.01	0.065	0.023	0.013	0.051	0.027	0.032
1,2,3,7,8-PeCDF	0.05	ND (0.003)	ND (0.001)	0.009	0.004	0.003	0.01	ND (0.007)	ND (0.006)
2,3,4,7,8,-PeCDF	0.5	1.783	0.03	0.039	0.05	0.011	0.065	0.041	0.01
1,2,3,4,7,8-HxCDF	0.1	4.846	0.066	0.108	0.112	0.014	0.187	0.037	0.009
1,2,3,6,7,8-HxCDF	0.1	ND (0.003)	0.014	0.031	0.087	0.01	0.199	0.045	0.008
1,2,3,7,8,9-HxCDF	0.1	ND (0.005)	ND (0.002)	ND (0.007)	ND (0.005)	ND (0.005)	ND (0.01)	ND (0.009)	ND (0.012)
2,3,4,6,7,8-HxCDF	0.1	0.037	0.01	0.029	0.054	0.005	0.177	0.028	ND (0.01)
1,2,3,4,6,7,8-HpCDF	0.01	0.274	0.028	1.251	0.359	0.087	2.702	0.136	0.024
1,2,3,4,7,8,9-HpCDF	0.01	0.023	ND (0.003)	0.097	0.036	0.008	0.118	ND (0.016)	ND (0.01)
OCDF	0.001	0.055	0.018	0.821	0.122	0.056	1.073	0.061	0.034
Total PCDDs		4.1	0.6	59.3	8.946	2.7	30.7	3.7	0.95
Total PCDFs		7.0	0.2	2.5	0.850	0.2	4.6	0.4	0.14
Total PCDDs and PCDFs		11.1	0.8	61.8	9.796	2.9	35.3	4.1	1.09
Total PCDD and PCDF TEQs		1.5	0.04	0.3	0.4	0.03	0.65	0.12	0.03

Abbreviations: CDD, chlorinated dibenzodioxin; CDF, chlorinated dibenzofuran; T, tetra; Pe, penta; Hx, hexa; Hp, hepta; O, octa; ND, not detected within detection limits shown in parentheses.
[a]Analyses by Food Science Laboratory, Norwich, England. Half of detection limits for nondetected congeners used in calculation.
[b]"Fused" peaks: a small peak not fully resolved from one much larger. The contribution from 1,2,3,4,7,8-HxCDD is small.

Table 3. Dioxins, dibenzofurans, and dioxin TEqs in dairy products from U.S. supermarket (ppt, wet weight)[a]

Congener	TEF	Cottage cheese	Soft blue cheese	Heavy cream	Soft cream cheese	American cheese slices
2,3,7,8-TCDD	1	ND (0.003)	ND (0.05)	ND (0.04)	0.04	0.07
1,2,3,7,8-PeCDD	0.5	0.01	0.2	0.11	0.11	0.12
1,2,3,4,7,8-HxCDD	0.1	0.02	0.29	0.07	0.14	0.017
1,2,3,6,7,8-HxCDD	0.1	0.07	1.72	0.7	0.58	0.38
1,2,3,7,8,9-HxCDD	0.1	0.02	0.29	0.14	0.14	0.19
1,2,3,4,6,7,8-HpCDD	0.01	0.18	5.88	2.11	1.51	1.13
OCDD	0.001	0.34	5.93	1.54	1.5	1.6
2,3,7,8-TCDF	0.1	0.02	0.15	0.07	0.07	0.1
1,2,3,7,8-PeCDF	0.05	ND (0.006)	ND (0.05)	ND (0.04)	0.04	ND (0.05)
2,3,4,7,8-PeCDF	0.5	0.02	0.25	0.14	0.18	0.07
1,2,3,4,7,8-HxCDF	0.1	0.06	0.93	0.47	0.43	0.36
1,2,3,6,7,8-HxCDF	0.1	0.02	0.34	0.14	0.18	0.1
1,2,3,7,8,9-HxCDF	0.1	ND (0.006)	ND (0.1)	ND (0.04)	ND (0.04)	ND(0.05)
2,3,4,6,7,8-HxCDF	0.1	0.01	0.15	0.11	0.14	0.07
1,2,3,4,6,7,8-HpCDF	0.01	0.1	1.76	0.6	0.58	0.52
1,2,3,4,7,8,9-HpCDF	0.01	ND (0.03)	ND (0.34)	0.14	ND (0.18)	ND (0.12)
OCDF	0.001	0.06	1.08	0.29	0.29	0.3
Total PCDDs		0.6	14	5	4	4
Total PCDFs		0.3	5	2	2	2
Total PCDDs and PCDFs		0.9	19	7	6	6
Total PCDD and PCDF TEqs[b]		0.04	0.7	0.4	0.3	0.3

Abbreviations: CDD, chlorinated dibenzodioxin; CDF, chlorinated dibenzofuran; T, tetra; Pe, penta; Hx, hexa; Hp, hepta; O, octa; ND, not detected within detection limits shown in parentheses.
[a]Analyses by ERGO Forschungsgesellschaft mbH, Hamburg, Germany.
[b]Half of detection limits for nondetected congeners used in calculation.

from 0.3 to 3.0 pg/kg to 0.006 to 0.06 pg/kg. Thus, a vegetarian diet or higher percentage of fruits and vegetables in the diet might have previously unsuspected health advantages for adults along with the more commonly recognized cardiovascular benefits and decreased cancer risk.

The dietary habits and lower body weight of children may cause them to have a markedly higher intake of PCDDs and PCDFs than adults at the crucial time when their physical and mental capabilities are developing. In addition, the threshold for toxic effects of dioxins appears to be lower for the developing fetus and infant than for adults (*31*). The findings of high daily dioxin intake in nursing infants, which follows the lower but unavoidable transplacental intake *in utero*, reaffirm the potential health concern for this sensitive population.

Although controversial at present, new research has suggested that TCDD may not exhibit a threshold for the expression of certain biochemical responses (*32*), such as CYP1A1 induction, which is consistent with possible toxic effects from even the smallest amount of additional dioxin TEqs. Human tissue in some experiments seems to be about as sensitive to the toxic effects of dioxin as laboratory rats, a relatively sensitive species (*33*). Thus there is a need for further characterization of potential sources of human exposure to PCDDs and PCDFs in order to limit such exposure.

Although our findings present the first congener-specific analyses of dioxins in food in the United States, the dioxinlike polychlorinated biphenyls (PCBs), which act in an additive fashion with dioxins and dibenzofurans, were not measured. PCBs are generally present in considerably higher amounts than the PCDDs and PCDFs, and their TEqs would most likely increase and perhaps double the total dioxin toxicity of these samples. Further research clearly remains to be performed to fully characterize the levels of dioxinlike chemicals in American food.

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Table 4. Calculated PCDD and PCDF intake from various food groups for the U.S. adult general population

Food group	Consumption rate (g/day)[a]	Range of PCDD/F TEq in food (wet weight; pg/g) Low	High	Daily human intake: Range total TEq (pg) Low	High	Range TEq/kg BW (pg)[b] Low	High
Beef	88	0.04	1.50	3.52	132.00	0.054	2.031
Pork	28	0.03	0.30	0.84	8.40	0.013	0.129
Poultry[c]	31	0.03	0.03	0.93	0.93	0.014	0.014
Fish	18	0.02	0.13	0.36	2.34	0.006	0.036
Milk[c]	254	0.04	0.04	10.16	10.16	0.156	0.156
Other dairy products	55	0.04	0.70	2.20	38.50	0.034	0.592
Fruits and vegetables	283	—	—	—	—	—	—
Total range				18.0	192.3	0.3	3.0

[a]Consumption rates from Yang and Nelson (*26*).
[b]Assuming 65 kg adult weight.
[c]Milk and poultry data from one sample each.

Table 5. Estimated daily intake of PCDDs, PCDFs, and dioxin toxic equivalents for males at different ages[a]

Age group (years)	Food group	Consumption rate (g/day)[b]	Mean PCDD and PCDF concentration range in food (pg/TEq/g) Low	High	Daily TEq intake (pg) Low	High	Average weight (kg)	Daily TEq intake (pg/kg) and % contribution from each food group Low	%	High	%
Birth–1	Human milk	600	0.43	0.64	258.00	384.00	7.3	35.34	100.0	52.60	100.0
Birth–1	Soy formula	600	0.001	0.002	0.54	1.20	7.3	0.07	100.0	0.16	100.0
1–4	Dairy products	417	0.04	0.70	16.68	291.90	13.6	1.23	84.9	21.46	67.3
	Meat	94	0.03	1.50	2.82	141.00	13.6	0.21	14.4	10.37	32.5
	Fish	7	0.02	0.13	0.15	0.95	13.6	0.01	0.7	0.07	0.2
	Total				20	434		1.4		32	
5–9	Dairy products	503	0.04	0.70	20.12	352.10	20.5	0.98	82.8	17.18	63.8
	Meat	132	0.03	1.50	3.96	198.00	20.5	0.19	16.3	9.66	35.9
	Fish	11	0.02	0.13	0.23	1.48	20.5	0.01	0.9	0.07	0.3
	Total				24	552		1		27	
10–14	Dairy products	565	0.04	0.70	22.60	395.50	41.0	0.55	80.5	9.65	60.1
	Meat	174	0.03	1.50	5.22	261.00	41.0	0.13	18.6	6.37	39.7
	Fish	13	0.02	0.13	0.26	1.69	41.0	0.01	0.9	0.04	0.3
	Total				28	658		0.7		16	
15–19	Dairy products	562	0.04	0.70	22.48	393.40	67.0	0.34	75.8	5.87	53.3
	Meat	228	0.03	1.50	6.84	342.00	67.0	0.10	23.1	5.10	46.4
	Fish	16	0.02	0.13	0.32	2.08	67.0	0.00	1.1	0.03	0.3
	Total				30	737		0.4		11	
>20	Dairy products	296	0.04	0.70	11.84	207.20	70.0	0.17	61.9	2.96	37.4
	Meat	229	0.03	1.50	6.87	343.50	70.0	0.10	35.9	4.91	62.1
	Fish	21	0.02	0.13	0.42	2.73	70.0	0.01	2.2	0.04	0.5
	Total				19	553		0.3		8	

[a]Totals are rounded.
[b]Consumption rates from Yang and Nelson (*26*).

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